NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY

SUBMARINE BASE, GROTON, CONN.

REPORT NUMBER 1121

ESTIMATING NOISE LEVELS WITHIN DRY DIVING HELMETS DUE TO EXTERNAL SOURCES

by

Paul F. SMITH

Naval Medical Research and Development Command
Research Work Unit 63713N-M0099.01C-5013

Released by:

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ABSTRACT

Data obtained from the Naval Coastal Systems Center was analyzed to determine what sound levels exist within current U.S. Navy diving helmets when divers are exposed to intense waterborne noise. Other research was reviewed to establish similar relationships for other diving systems that are of interest to the U.S. Navy. The results indicate that features of helmet construction (materials and shape) affect the transfer of sound from water to within helmets. A single medically conservative transfer function was identified that may be applied on an interim basis to current U.S. Navy diving helmets. Additional research that needs to be accomplished to develop more adequate transfer characteristics is outlined.

Noise Levels within diving helmets due to external sources

When divers using "hard-hat" or soft, dry-suit helmets are exposed to noise originating in water from hand-held tools, active sonars or other sources, what sound levels would be expected within the diving helmet?

Paul Gould and David Wyman of the Naval Coastal Systems Center measured noise levels produced by several underwater hand-held tools (Gould and Wyman, 1982a-h). Among their many tests were measurements of noise levels in the water about 2 m from diver-operated tools and measurements made within an unmanned U.S. Navy MK 12 Surface Supported Diving System helmet that was also located about 2 m from the tool. They used a MRI 319 hydrophone to measure waterborne sound. A Bruel & Kjaer model 4134 1/2" microphone mounted adjacent to one ear position of a mannequin head was used to measure noise within the MK 12 helmet. The microphone was calibrated at 1 atm but not at depth. Both waterborne and helmet noise were recorded on tape and 1/3-octave-band analyses were performed on the recorded data. The noise levels within the helmet were presented by Gould and Wyman as "A" weighted levels, but the waterborne noise data were not weighted. Eight pairs of such measurements presumed to have been made under comparable (but not simultaneous) conditions were abstracted from figures presented in their reports. As described below, those data were used to develop a single function (called a transfer characteristic) describing the transfer of sound from water to within the helmet.

ANALYSIS AND RESULTS

Since the Gould and Wyman noise levels within the MK 12 were A weighted, the appropriate weighting factor was added to each reported 1/3 octave band to obtain the un-weighted helmet band level. Then those un-weighted band levels were subtracted from the corresponding band levels of the waterborne sound. The resulting transfer characteristics for sound from water to within the MK 12 helmet are given in Figure 1.

As Figure 1 shows, there was considerable variability in the transfer of sound from water to within the helmet from tool to tool. As there is no obvious reason why different tool noises should produce different transfer characteristics the variability is considered to be due to normal experimental error. However, the measurements used for the present analysis were not simultaneous. Output levels of the tools may vary over time and from user to user. Similar variability might have been observed if the same tool had been used as a noise source for eight independent (non-simultaneous) pairs of measurements obtained from diver-operated tools.

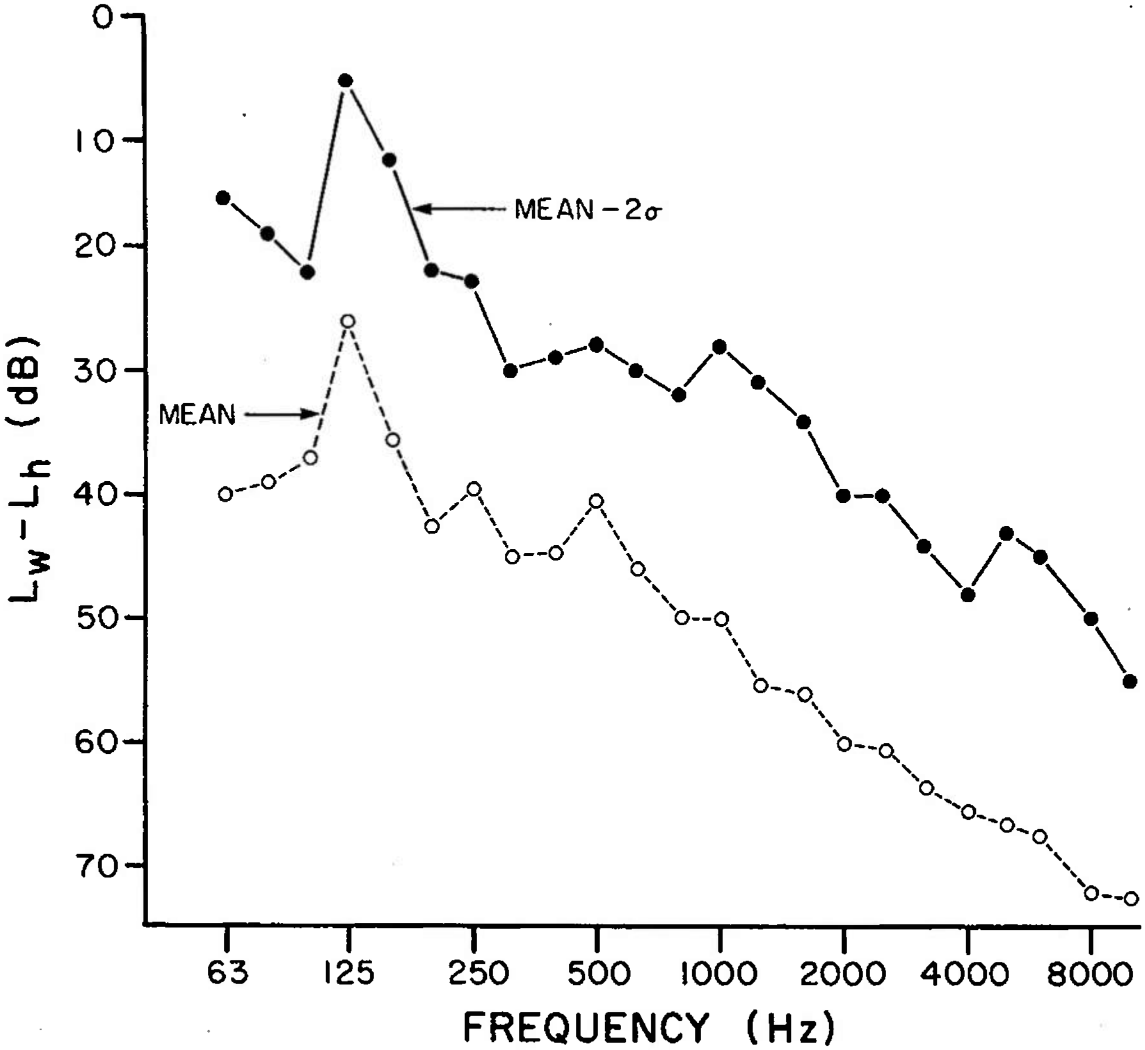

Figure 2. The lower curve is the mean difference between noise levels in water (L_w) and within the MK 12 diving helmet (L_h) for various 1/3 octave bands for eight measurements given in Figure 1. The upper curve is the mean less 2 standard deviations at each 1/3 octave band and is designated the Gould-Wyman transfer characteristic for MK 12.

Some data on transfer characteristics are available for other diving helmets. In a preliminary study, Molvaer et al. (1980) measured noise levels within a manned Diving Systems International Superlite 17 helmet and in the water adjacent to the helmet. They used an electroacoustic projector (J9) as the sound source rather than uncontrolled tool noise as was used by Gould and Wyman. Hydrophones were used both under the soft hood within the helmet and in the water. The internal measurements may have been contaminated by diver-originated noise or gas-flow noise and the authors expressed uncertainty concerning how the internal hydrophone should be calibrated (as microphone or as hydrophone). They caution that measurements taken within the helmet may not be completely reliable. Their external

Molvaer and Gjestland (1981) reported transfer characteristics for Superlite 17 and the standard Siebe-Gorman helmet using a mannequin head within the helmets. Their results are also presented in Figure 3 (taken from their Figure 4). For the Superlite 17 the transfer characteristic for the manned condition (Molvaer et al., 1980) does not completely agree with that for the unmanned condition. In general, however, less sound transfers into the Superlite 17 at high frequencies than at low as is the case for the MK 12. The transfer characteristic for the Siebe-Gorman shows a maximum attenuation at 500 Hz with a rather flat transfer characteristic for 1 Khz to 4 kHz.

DISCUSSION

The transfer of acoustic energy from water to within a diving helmet depends primarily upon the ratio of the characteristic impedance (the product of the density and the sonic velocity in a medium) of water to the characteristic impedance of the gas within the helmet, and secondarily upon other factors discussed below. The impedance of seawater is relatively invariant but, for a given breathing-gas mixture, the characteristic impedance of the helmet gas will increase with ambient pressure (depth). Thus as depth increases, the difference in impedances between the water and the helmet gas will decrease and more energy will be transferred from the water to the helmet gas. If helium-oxygen rather than compressed air is used as a breathing gas the ratio of wavelengths in water to the wavelengths within the helmet will be different and this factor will alter the transfer characteristic and also standing wave patterns within the helmet. All of the data reviewed here were taken at fixed depths with compressed air in the helmet. Those data provide no means for evaluating changes in breathing-gas impedance on the transfer characteristics.

Other important variables affecting the transfer characteristic are sound frequency (rather, the wavelengths both in the water and within the helmet), the dimensions of the helmet, and perhaps also the construction of the helmet (materials and shape). The Gould-Wyman transfer characteristic does not vary smoothly with frequency as would be expected for sound incident on a semi-rigid sphere. The characteristic in Figure 2 could have been smoothed on the assumption that the irregularities across frequency merely reflect experimental error. However, those irregularities may also reflect some narrow-band noise at 1 atm in air with threshold shifts incurred with exposure to noise within the helmet (due to noise in the water) at selected depths and gas mixtures to verify the noise level predictions of the transfer characteristics derived from the unmanned studies.

Until more precise measurements are available, however, the Gould-Wyman transfer characteristic in Figure 2. can be accepted as a medically conservative estimate of noise levels within MK 12 helmets due to noise levels in shallow water. The characteristic may also be used on an interim basis for EX 14 and MK 14 helmets given their similarities to MK 12 in construction. The Molvaer and Gjestland (1981) data should be used for the Superlite-17 and the standard Siebe-Gorman. However, the Gould-Wyman transfer characteristic may reasonably be expected to be conservative for any existing hard or soft dry helmet.

Molvaer, O.I. and Gjestland, T. (1981). Hearing damage to divers operating noisy tools underwater. Scand. J. Work Environ. Health, 7, 263-270.

Molvaer O.I., and Vestrheim, M. (1982). Noise in a standard dive helmet. Norwegian Underwater Technology Center Report 28-82.

Summit, J. and Reimers, S. D. (1971). Noise. A hazard to divers and hyperbaric chamber personnel. Aerospace Med., 42, 1173-1177.

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